SigNals Of Opportunity: P-band Investigation (SNOOPI)

2017 InVEST Award

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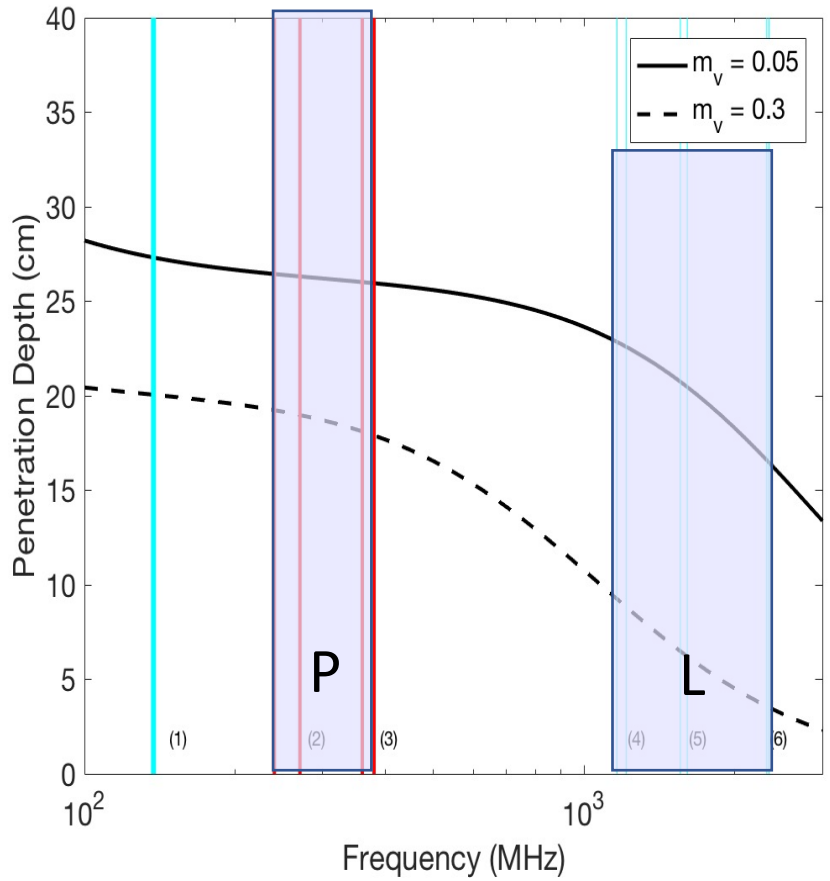
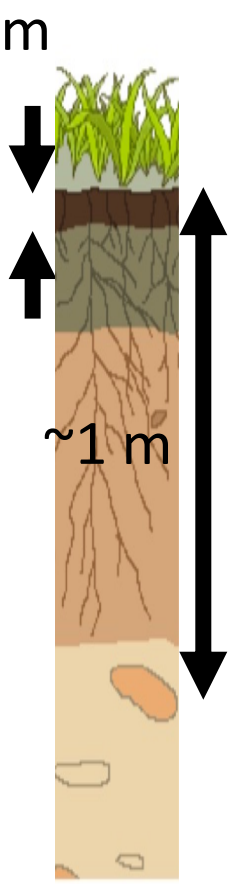
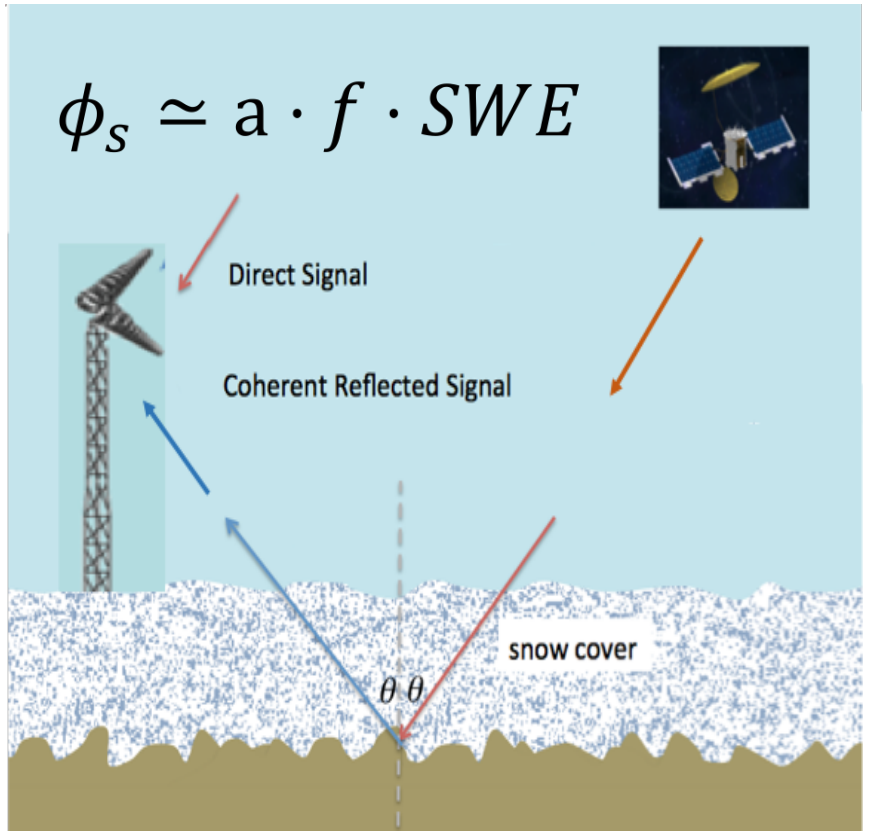
Motivation: P-band Remote Sensing



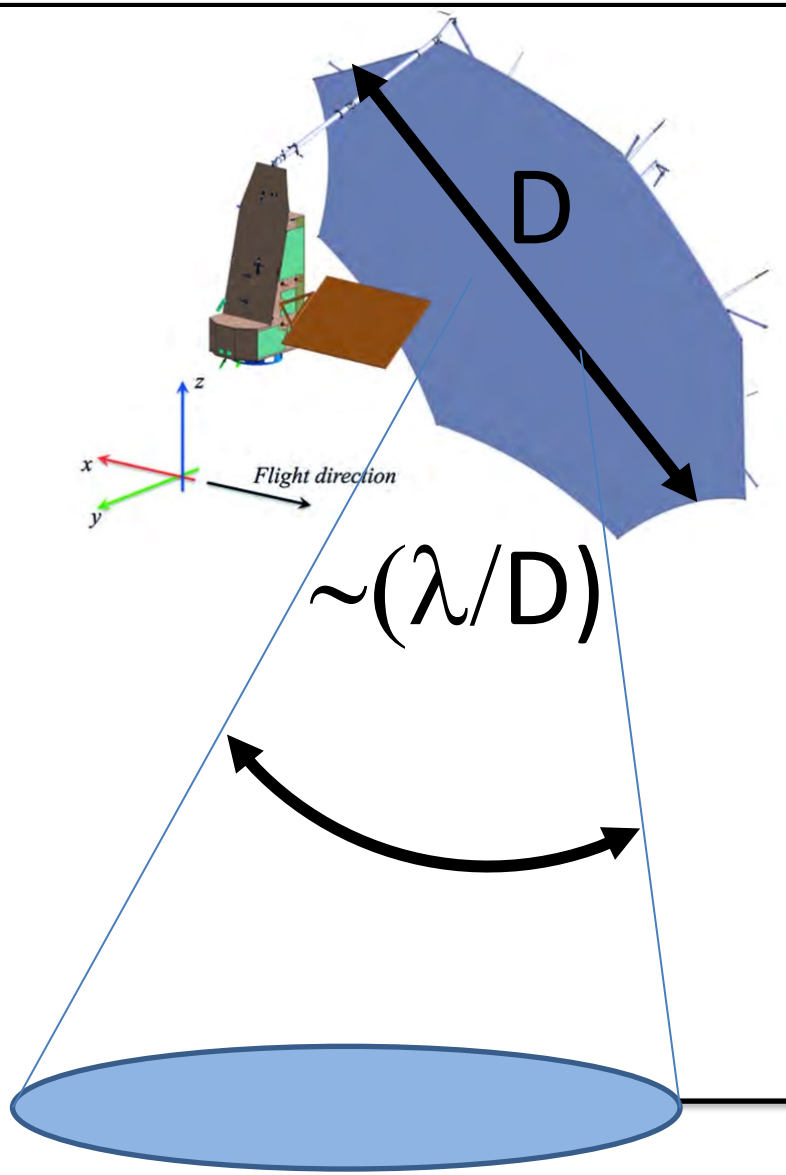


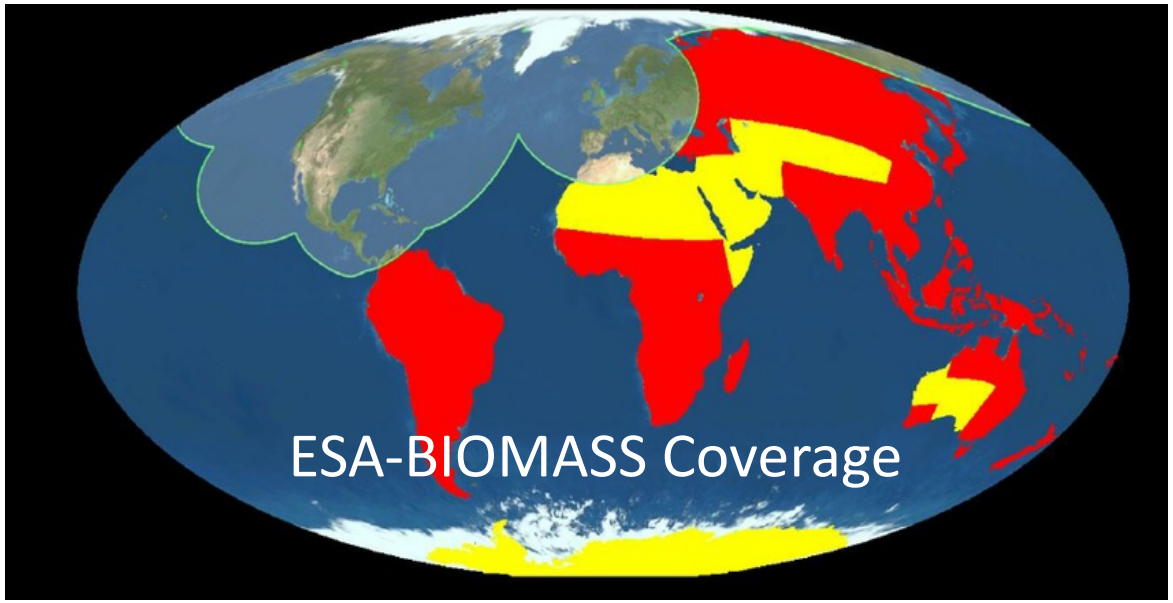
Root Zone Soil Moisture (RZSM)



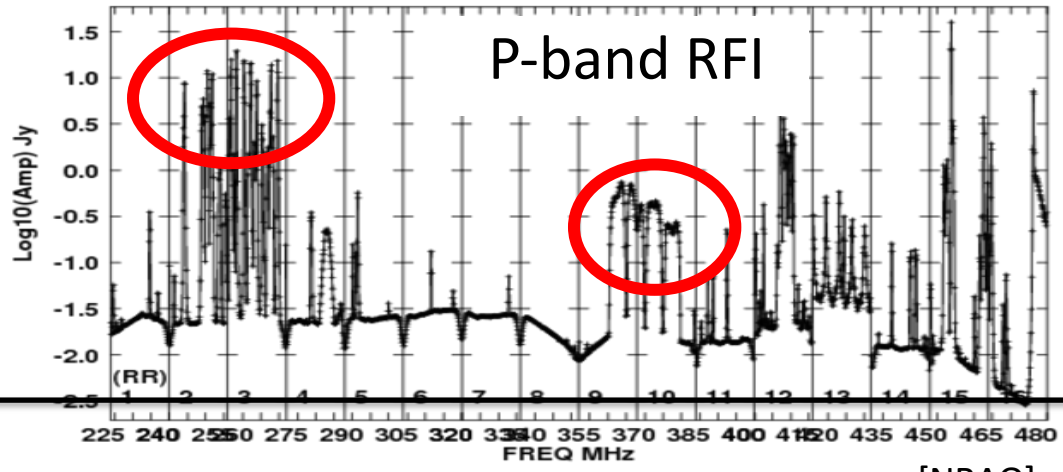
Snow Water Equiv. (SWE)

Why is P-band Difficult ?



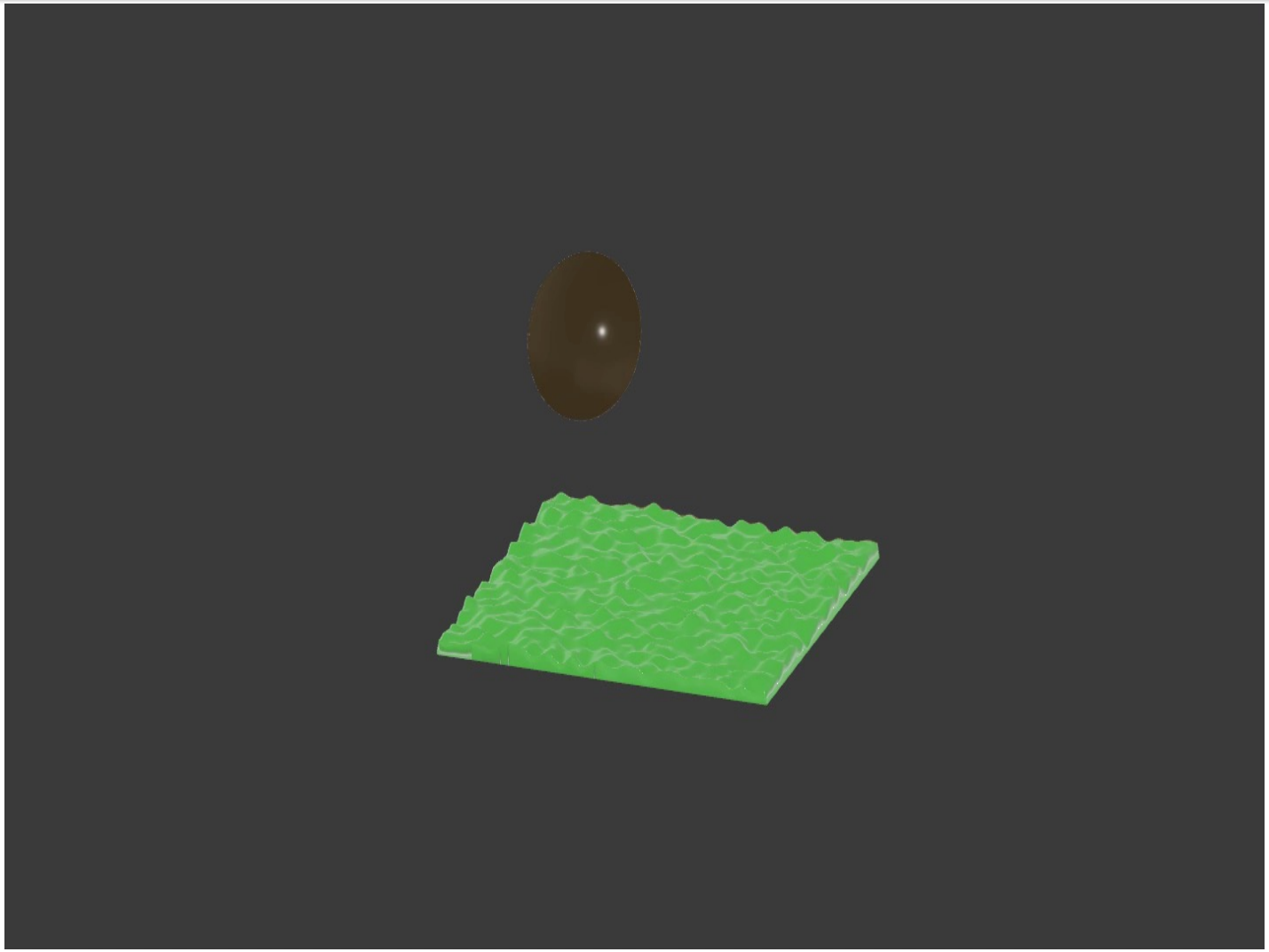


[Hélière, et al, EARSeL, 2013]



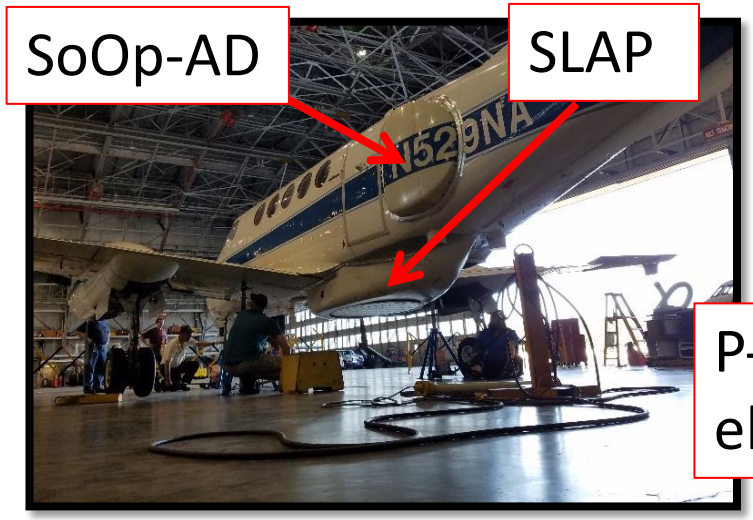
[NRAO]

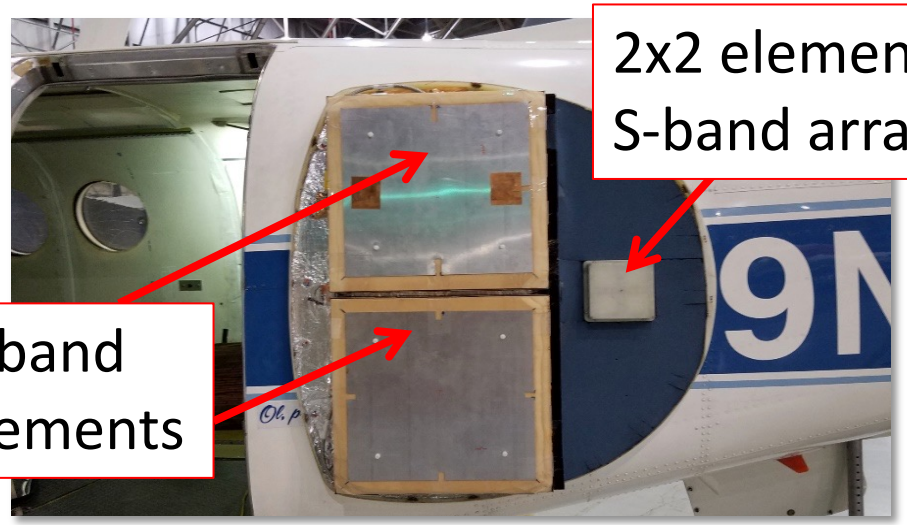
Signals of Opportunity

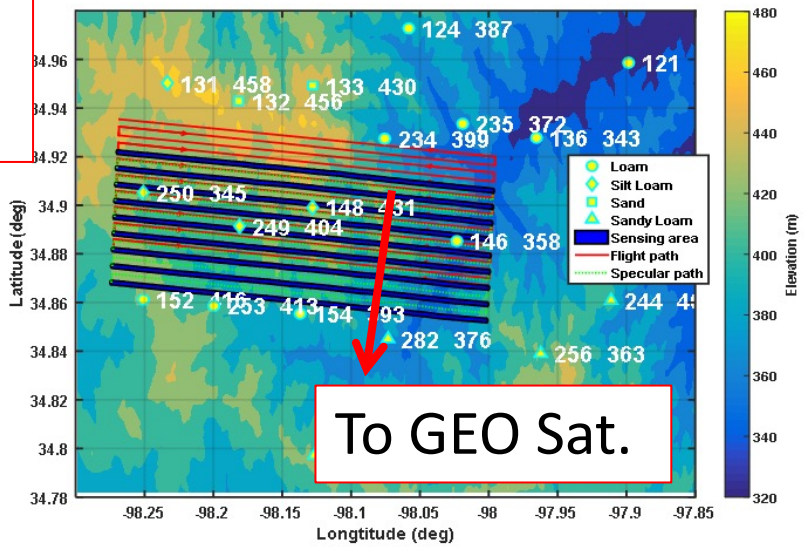


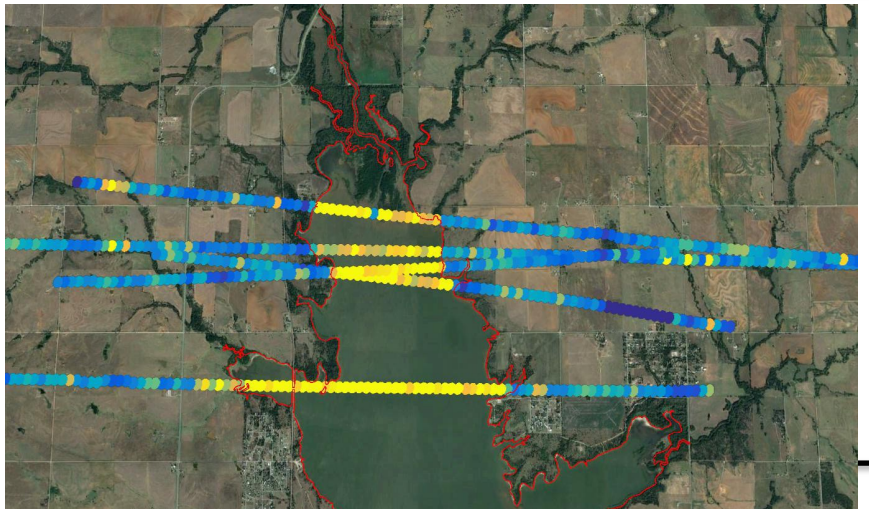
P-Band SoOp Heritage

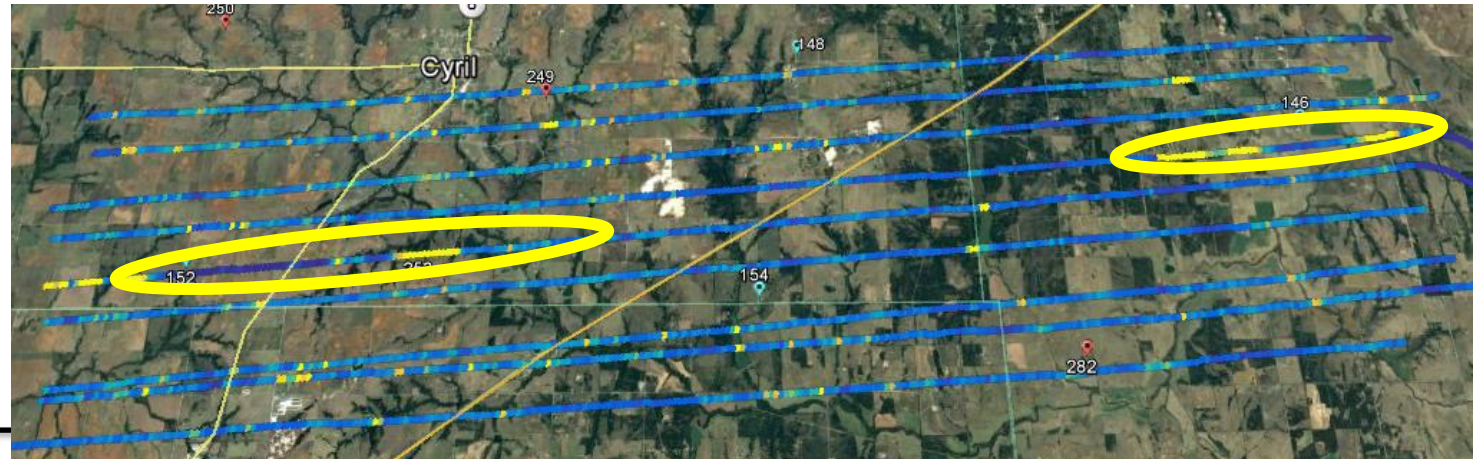
IIP-13 Award: Signals of Opportunity Airborne Demonstrator (SoOp-AD)





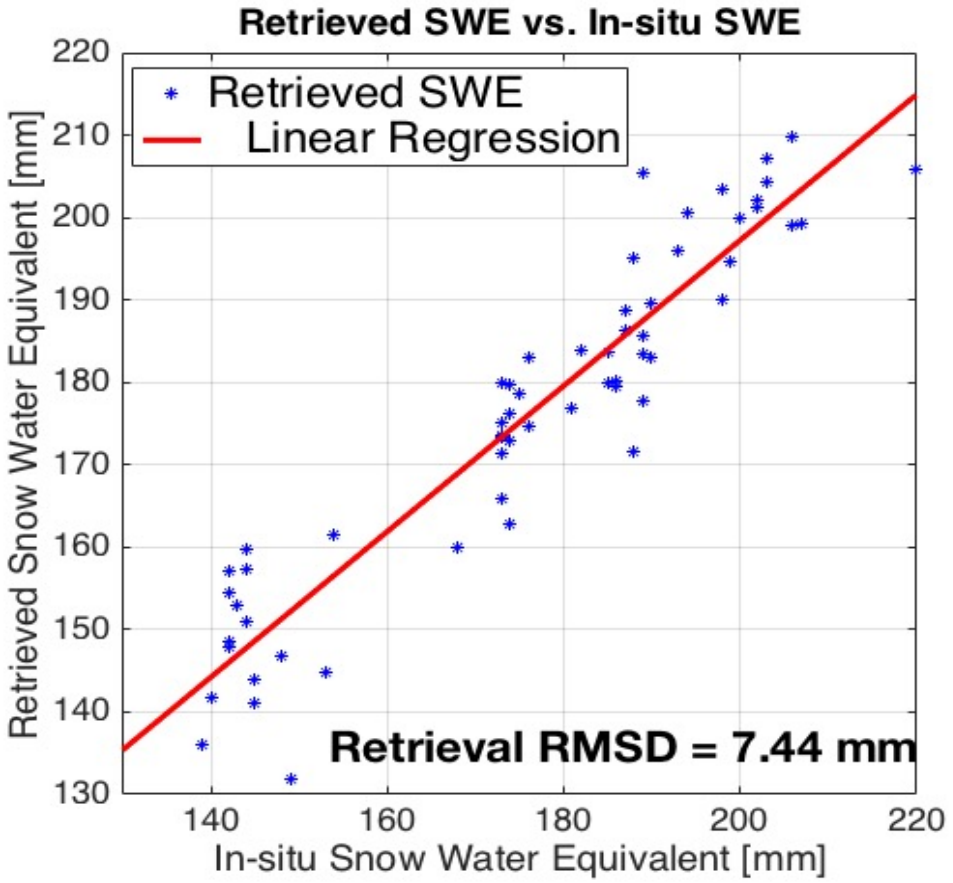


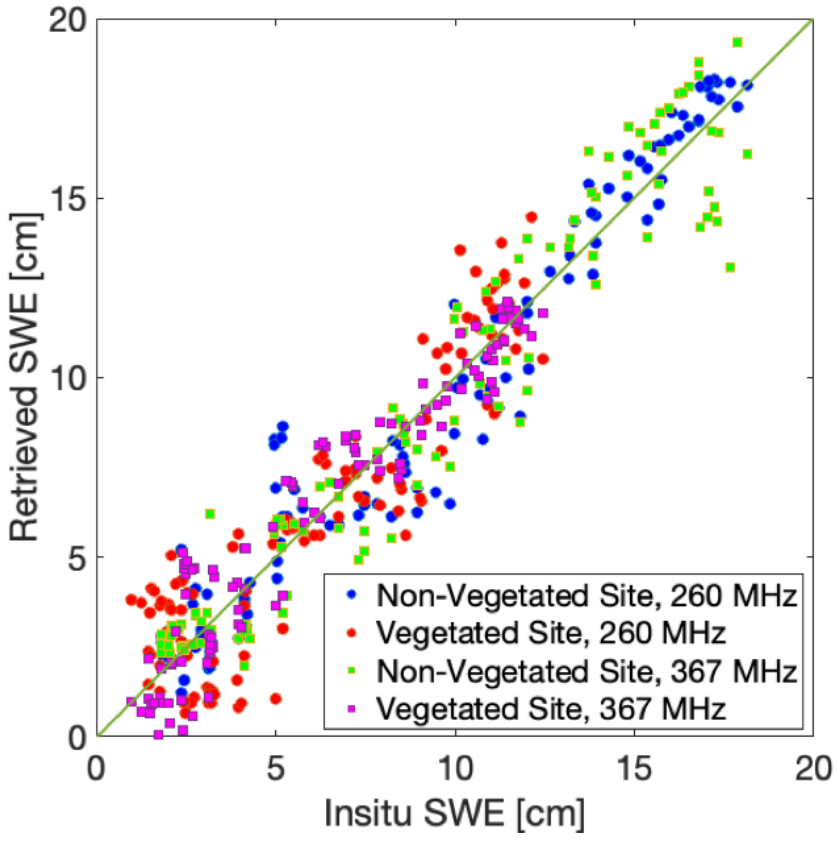




P-Band SoOp Heritage

- Snow observations (JPL RTD)



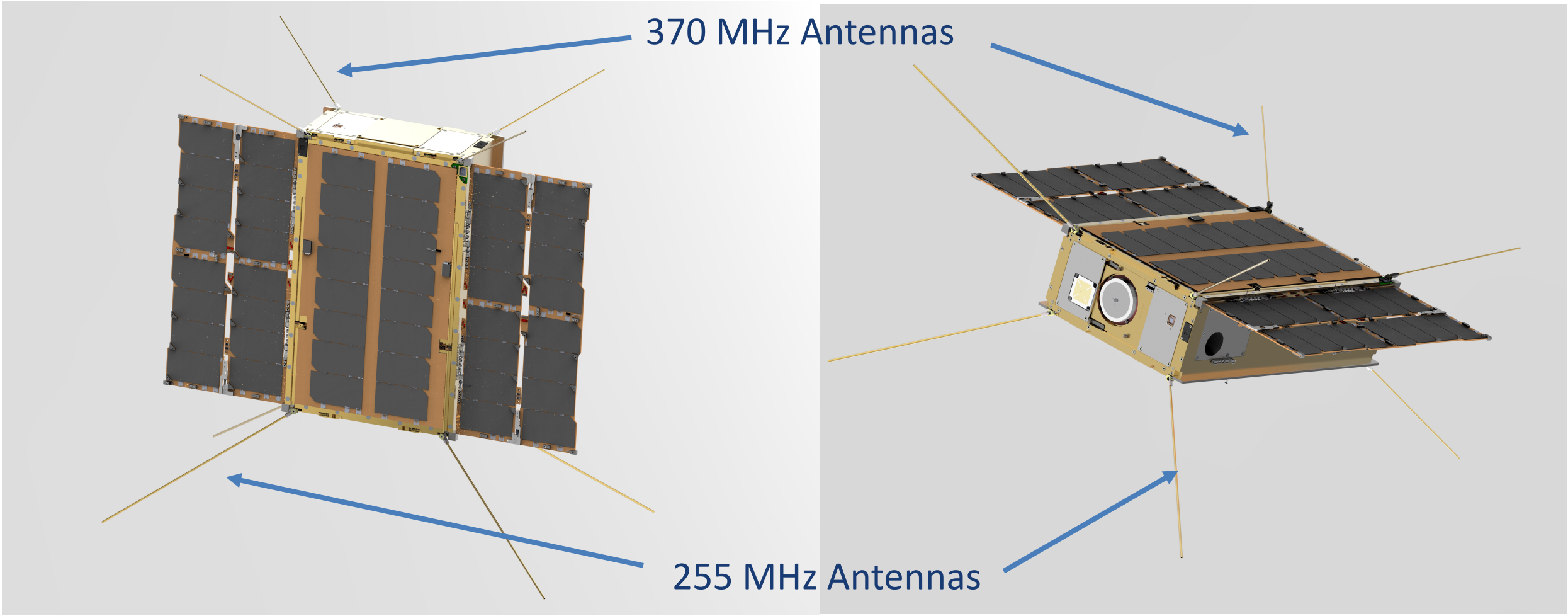


[Shah, et al., 10.1109/LGRS.2016.2636664]

Necessity of In-Space Validation

1. Validate **link budget** from orbital altitudes and speeds to quantify uncertainty in reflectivity and phase
2. Quantify **RFI effect** from space (broad field of view, global distribution of measurements)
3. Demonstrate model prediction and instrument tracking for orbital delay and Doppler with non-cooperative transmitter

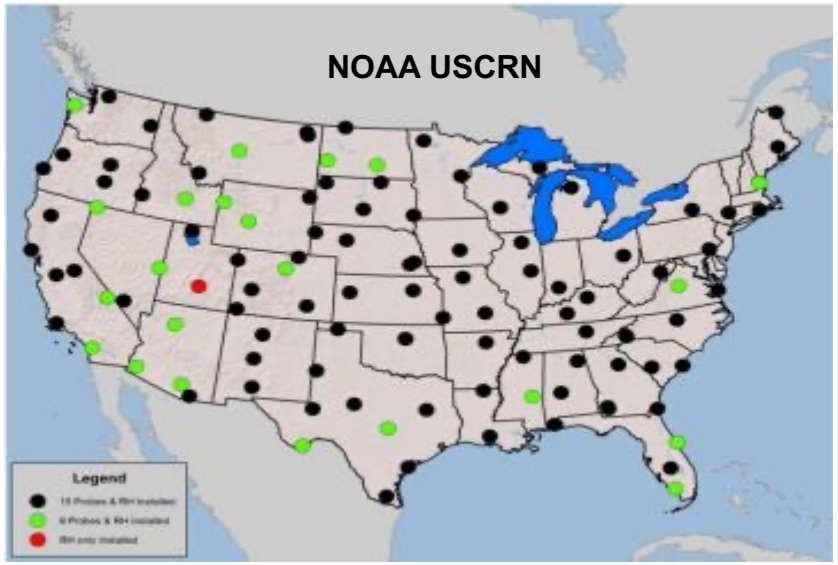
Spacecraft Design

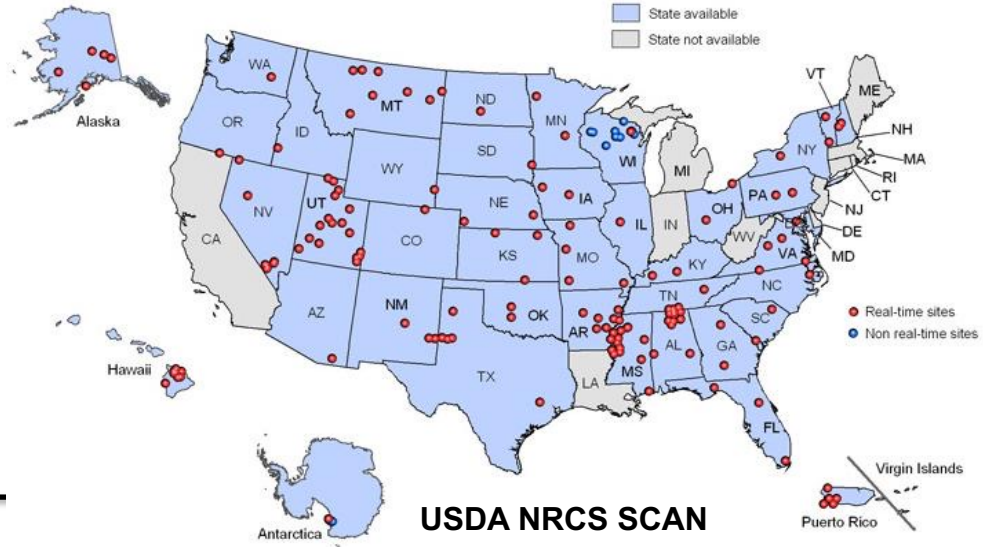


Mission Design: In-Situ Site Matchups

- SNOOPI will take advantage of the different validation sites located in different biomes (both core and sparse networks).
- SNOOPI observations inside the watershed will be compared to in situ observations
- SNOOPI observations will be compared to the sparse and model outputs to cover a wide range of biomes over CONUS

CVS	Location	Climate Regime	Land Cover Type
Walnut Gulch, ID	Arizona, USA	Arid	Shrub open
TxSON, TX	Texas, USA	Temperate	Grasslands
Fort Cobb, OK	Oklahoma, USA	Temperate	Grasslands/Croplands
Little Washita, OK	Oklahoma, USA	Temperate	Grasslands
South Fork, IA	Iowa, USA	Humid Continental	Row Crop
St. Joseph's, IN	Indiana, USA	Humid Continental	Row Crop
Little River, GA	Georgia, USA	Temperate	Cropland/natural mosaic
Yanco	Australia	Arid	Croplands



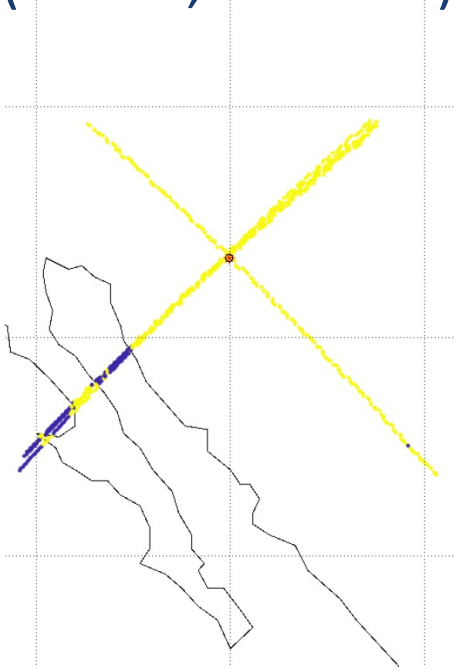


Mission Design

- SMAP Cal/Val Site Matchups (ISS orbit - 1 year):

Walnut Gulch

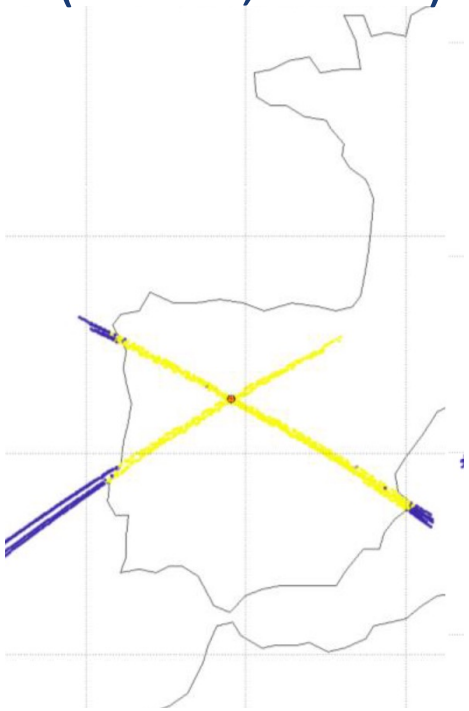
(31.75°, -110.03°)



5 arcs

REMEDHUS

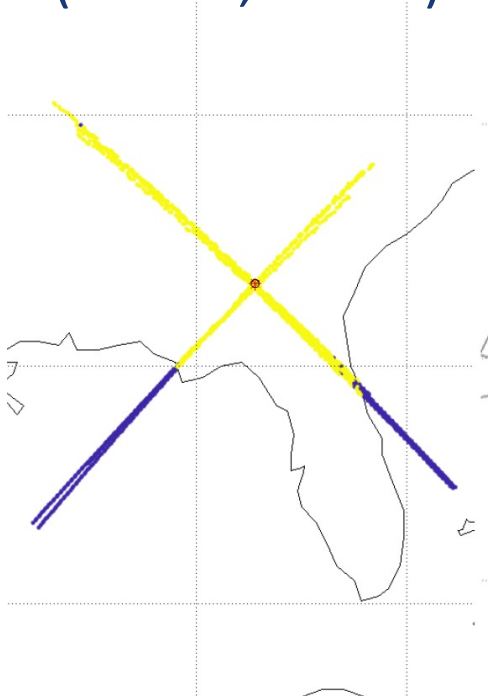
(41.29°, -5.46°)



12 arcs

Little River

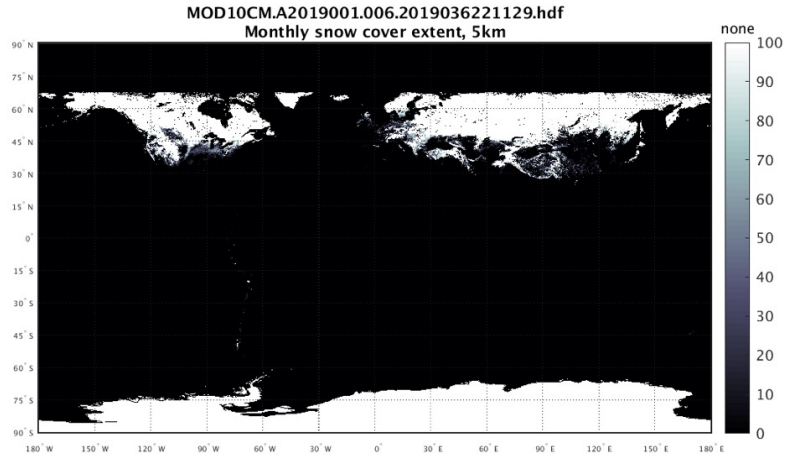
(31.67°, -83.6°)



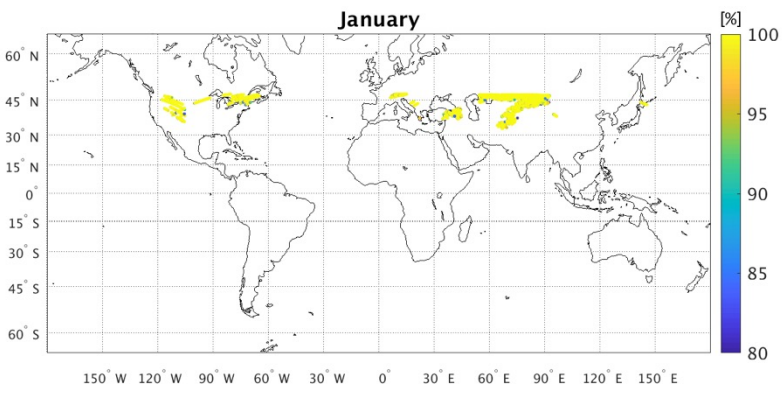
9 arcs

Mission Design: Snow Coverage

January

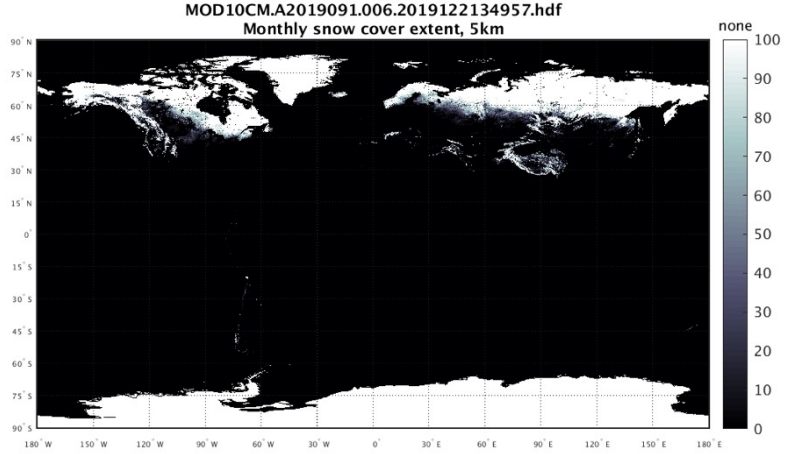


MODIS



SNOOPI

March



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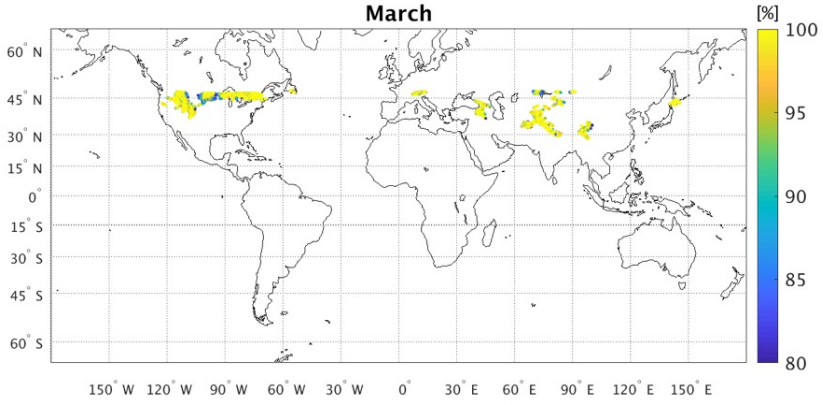
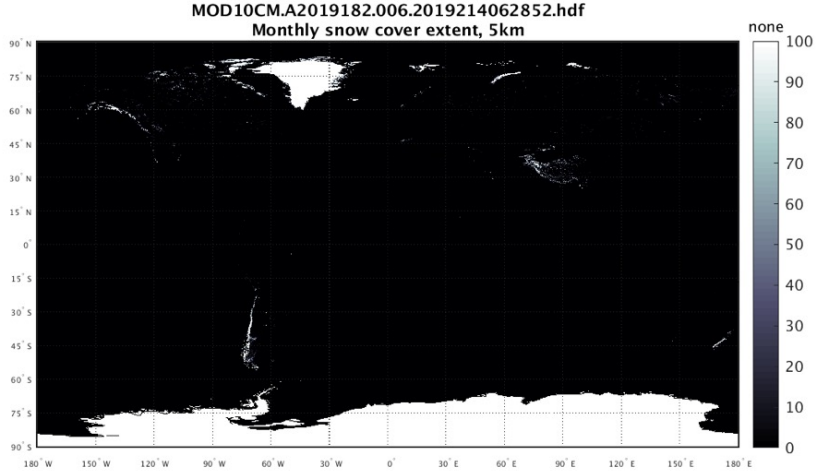


SNOOPI

June



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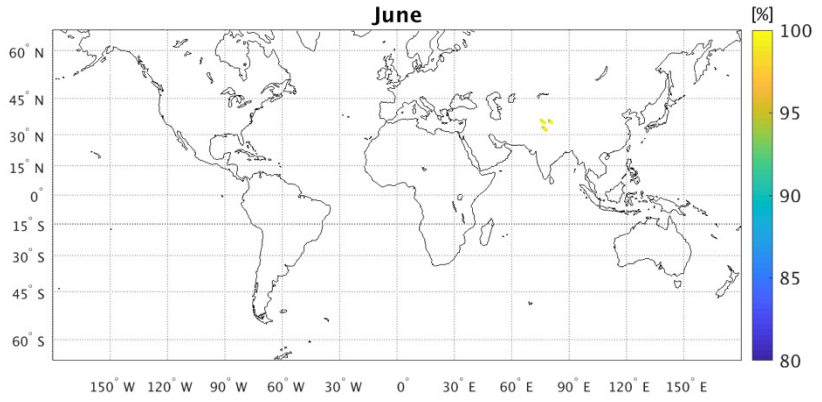
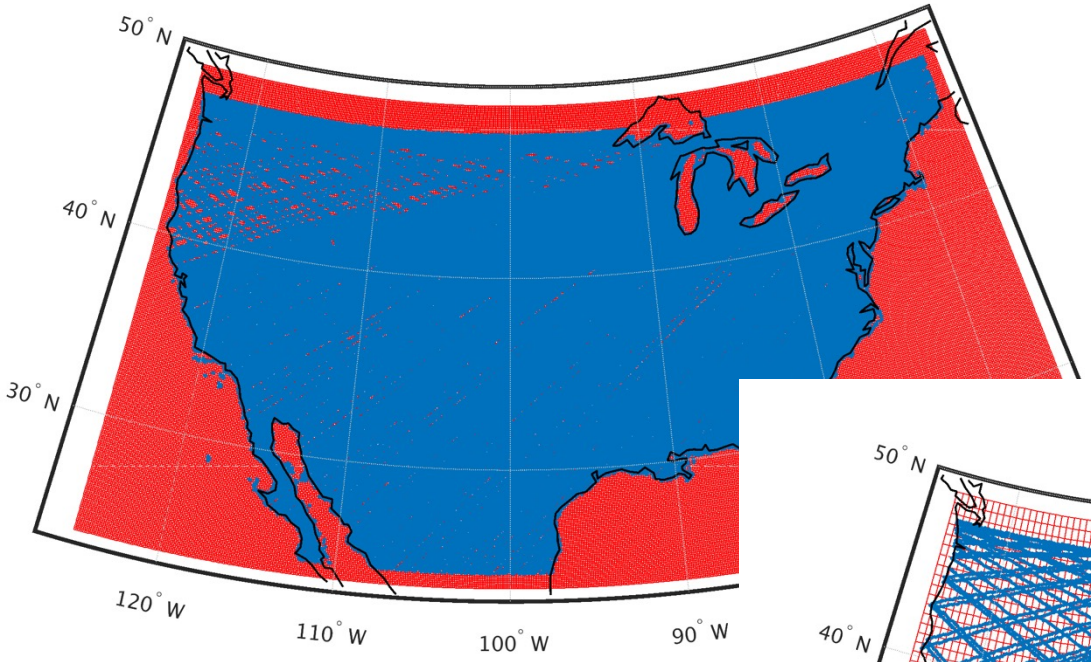
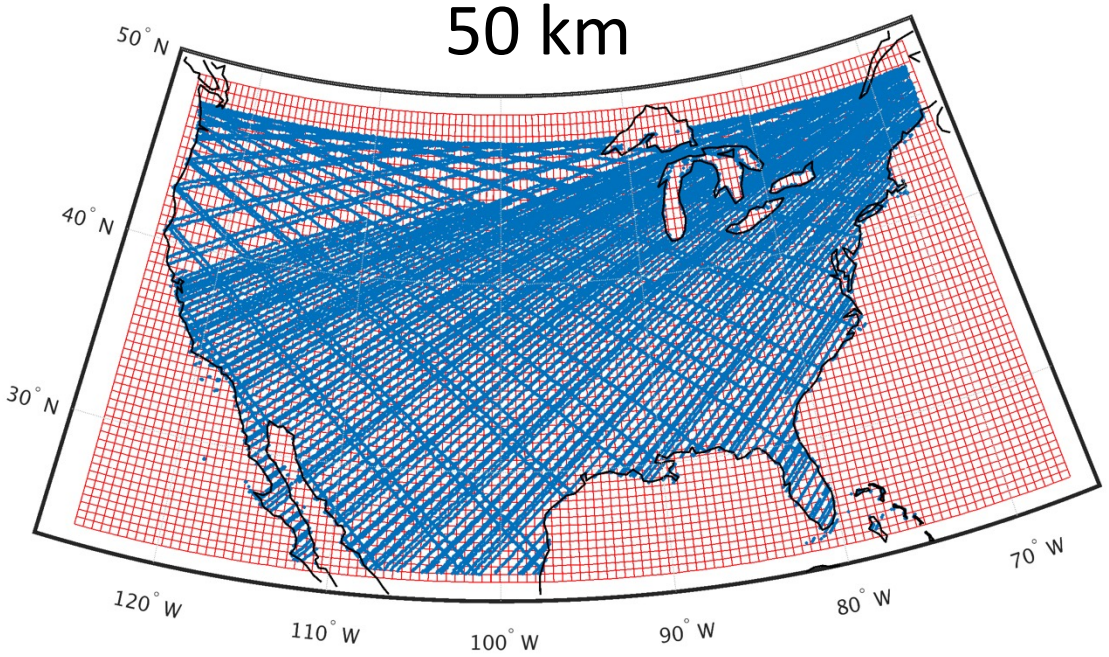


SNOOPI

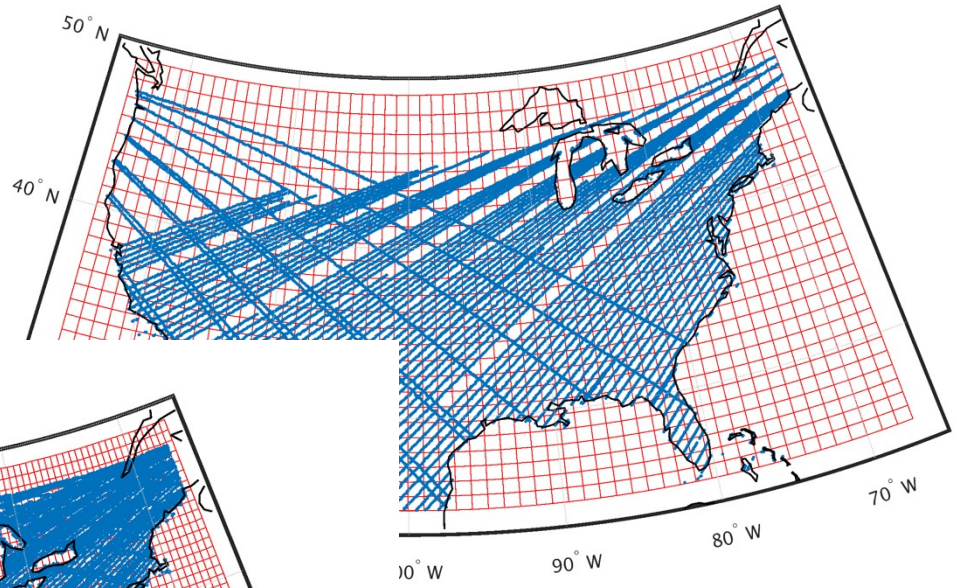
Mission Design: CONUS Mapping



10 km

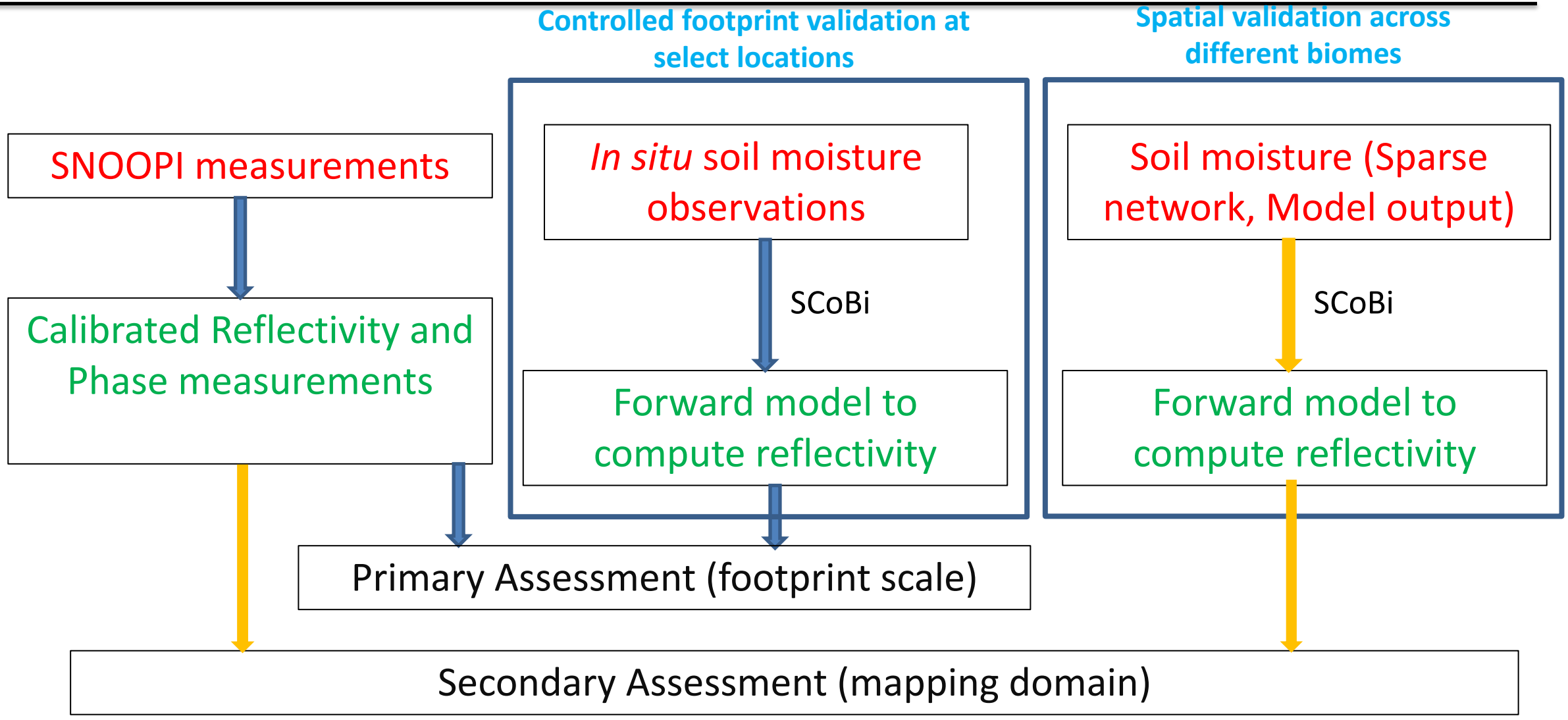


50 km



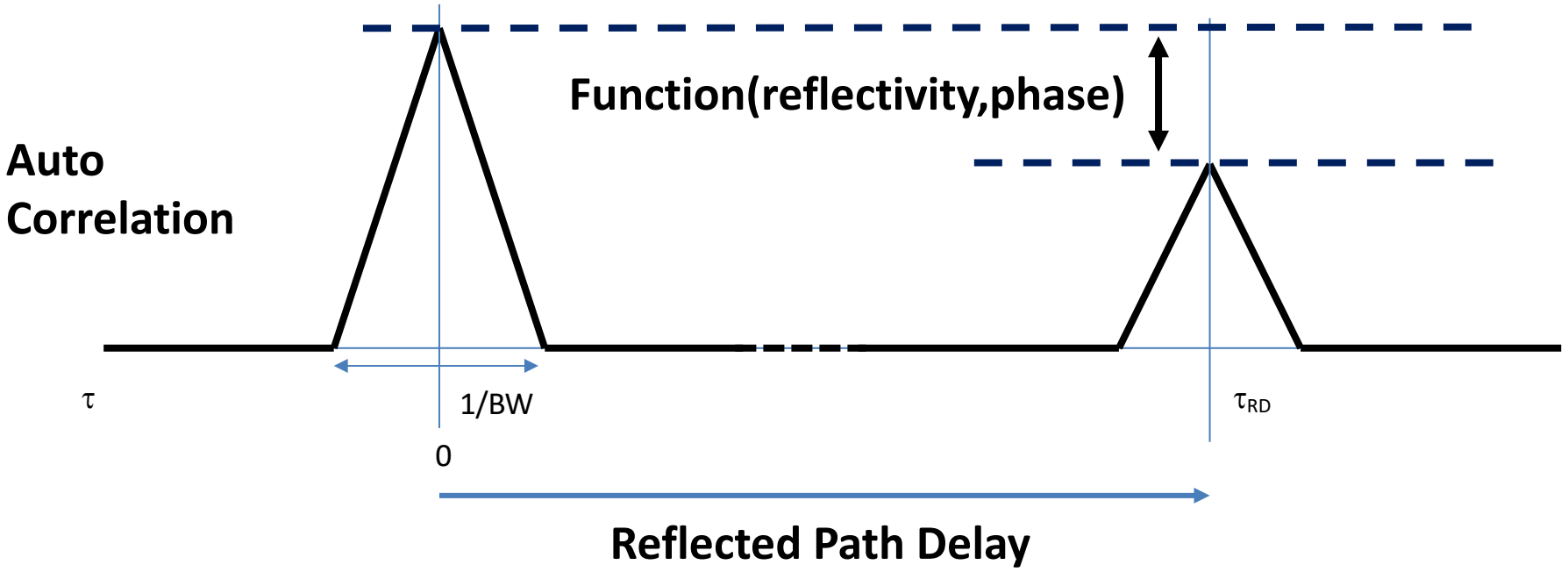
100 km

Data Validation Plan



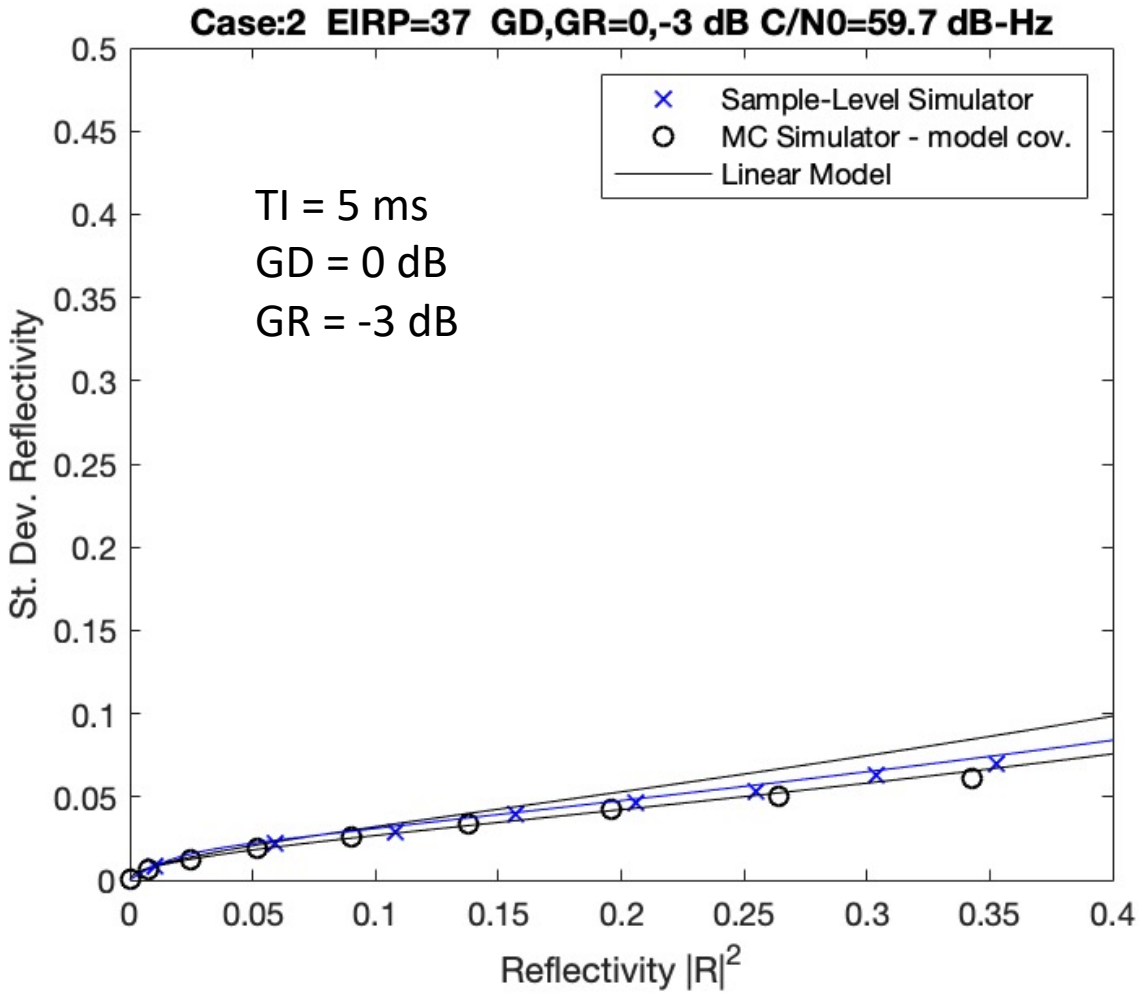
Instrument Science

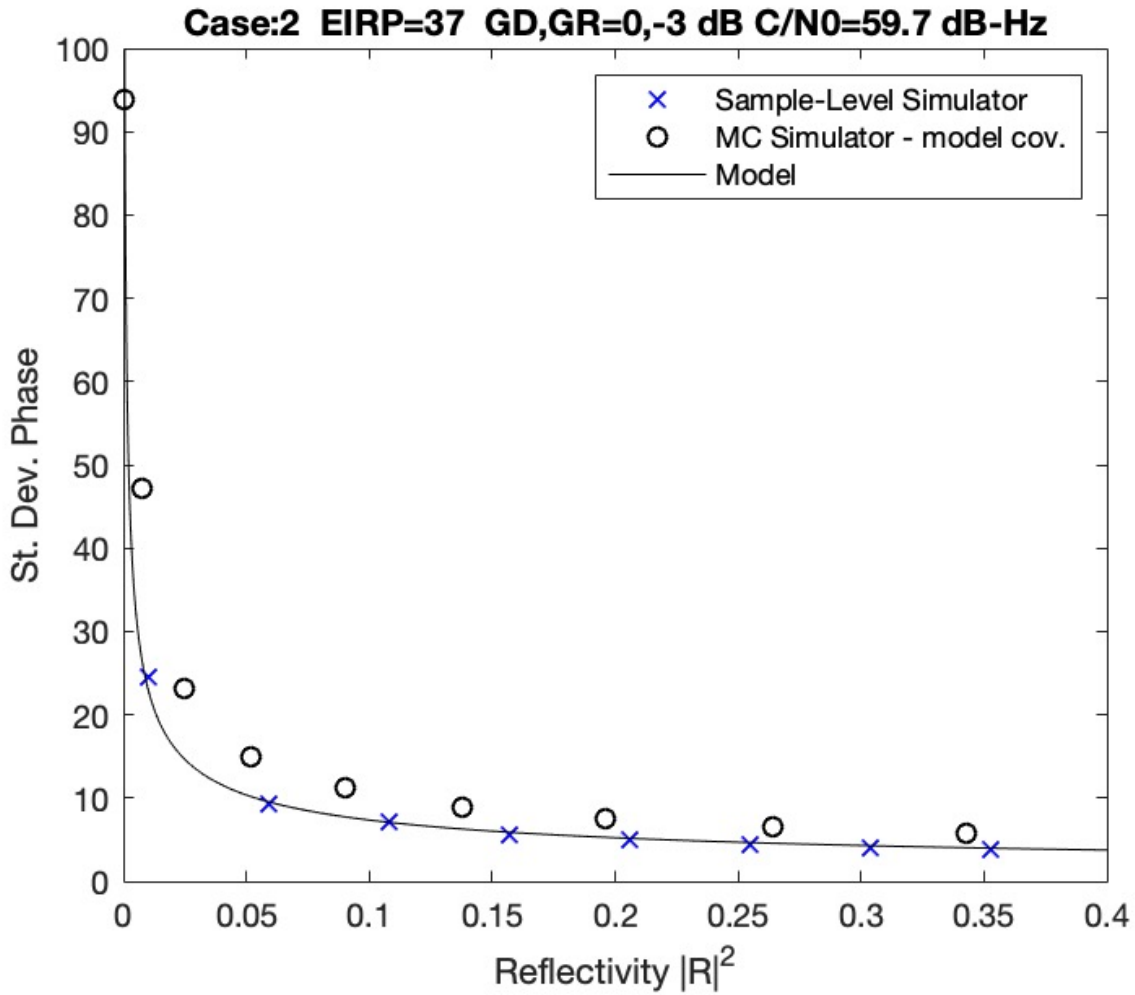
- ***Single antenna – Autocorrelation***



Two antennas with high isolation – not feasible with P-band on CubeSat sized platform

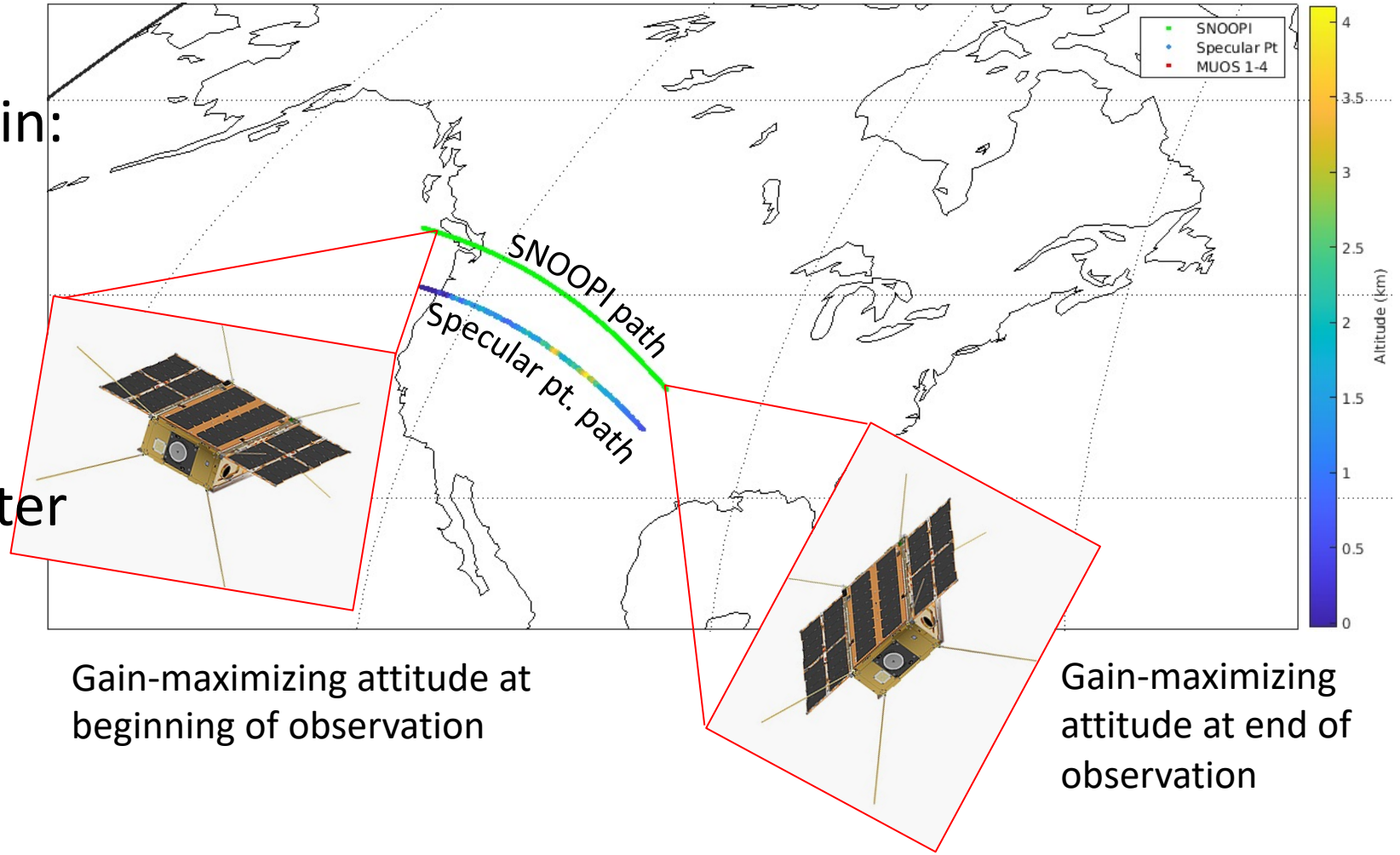
Instrument Science: Simulated Retrievals





Instrument Science: Attitude Optimization

- SNOOPI Attitude will be set to optimize antenna gain:
  - Maximize G_D
  - Constraint $|G_D-G_R|<3dB$
  - Slew rate and star tracker pointing constraints
- Attitude knowledge better than 0.1 deg

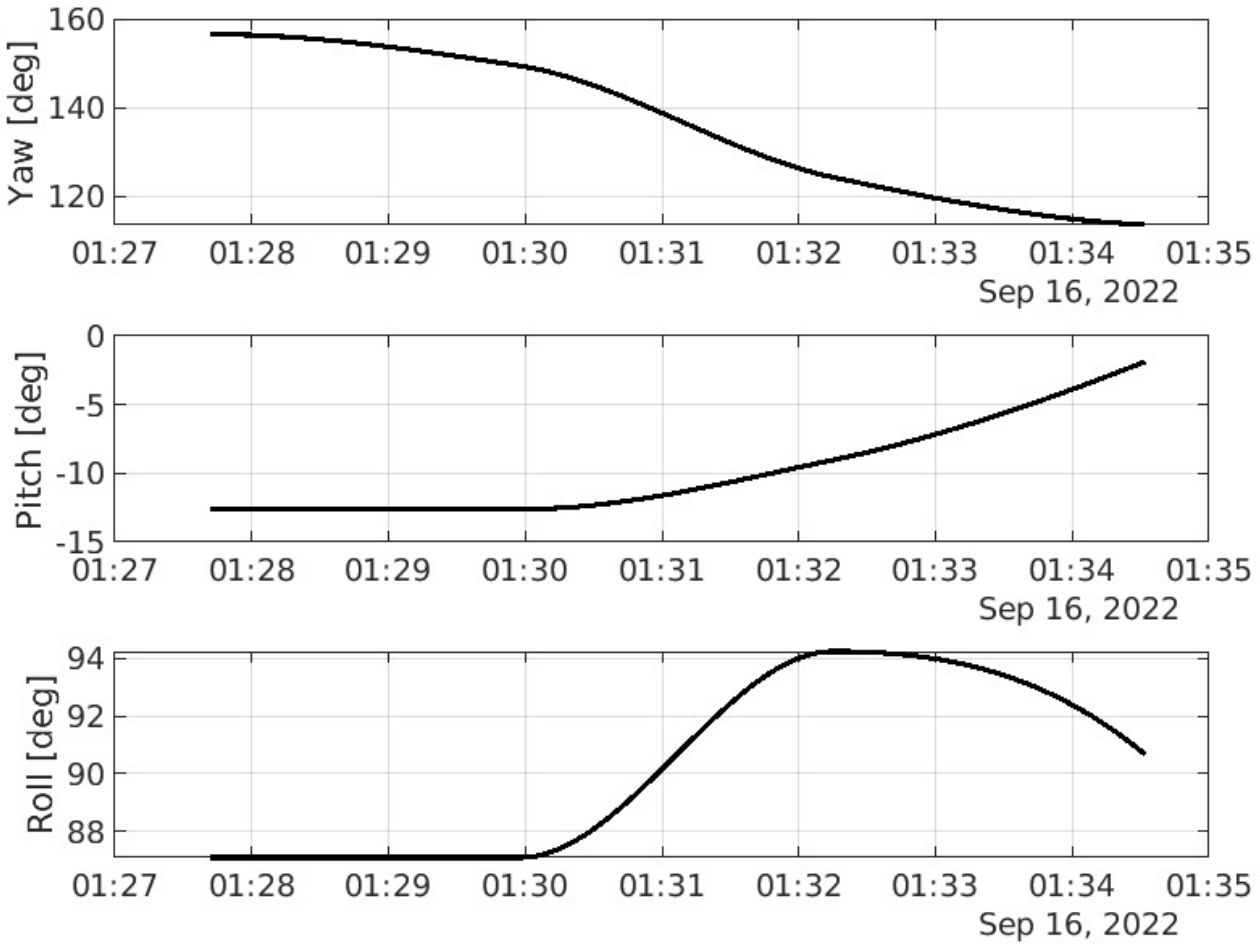


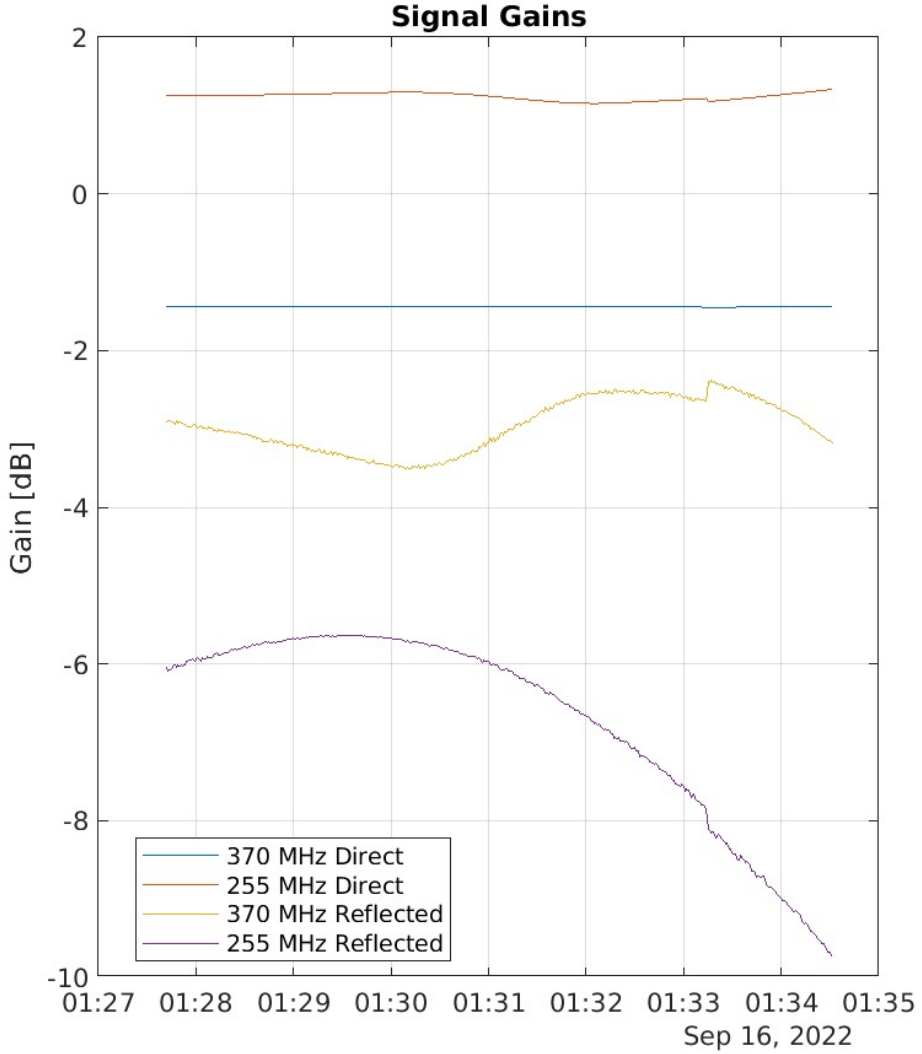
Gain-maximizing attitude at beginning of observation

Gain-maximizing attitude at end of observation

Instrument Science: Attitude Optimization

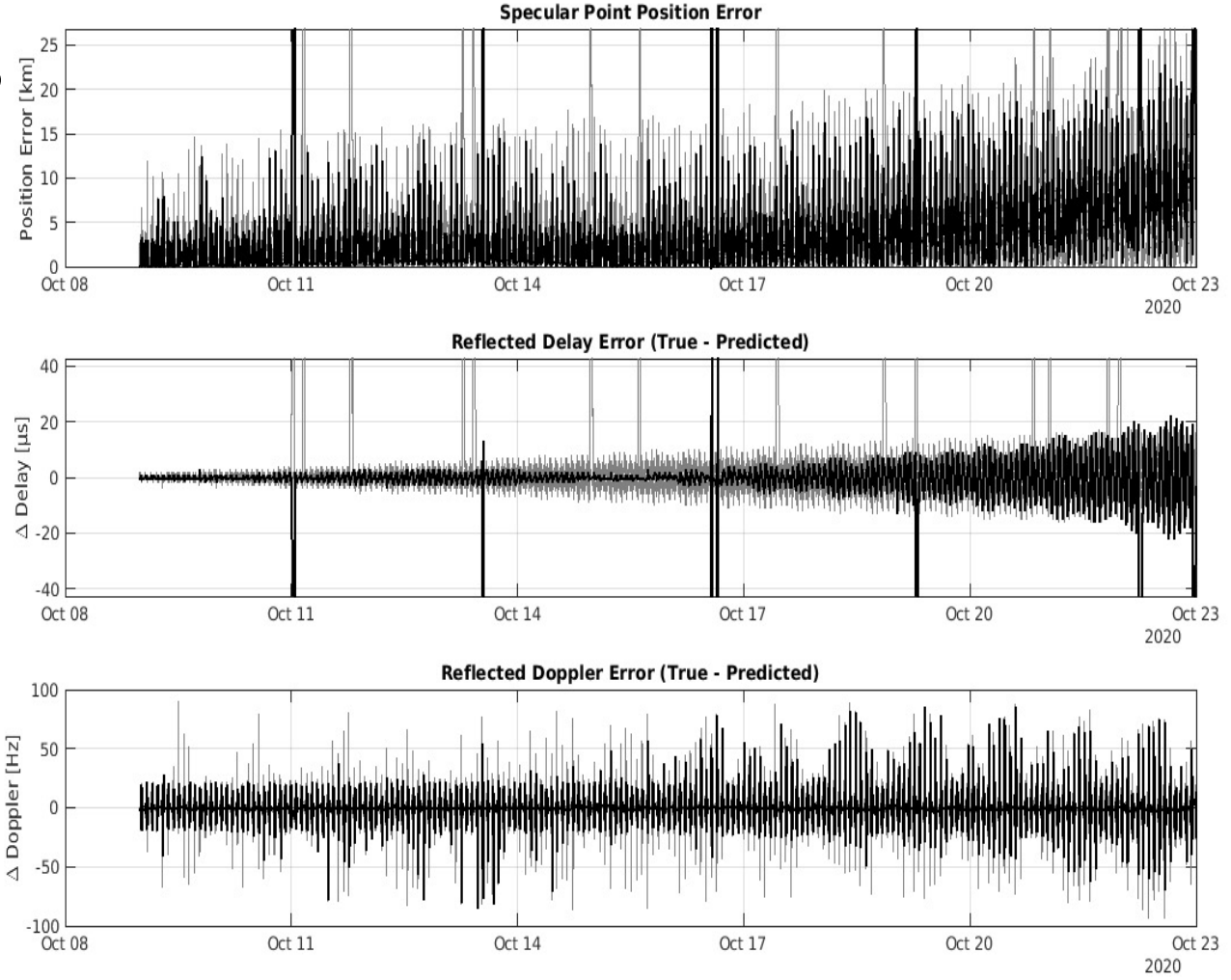
- Example optimization of an overpass over South Fork SMAP Cal/Val site:





Instrument Science: Delay-Doppler Map

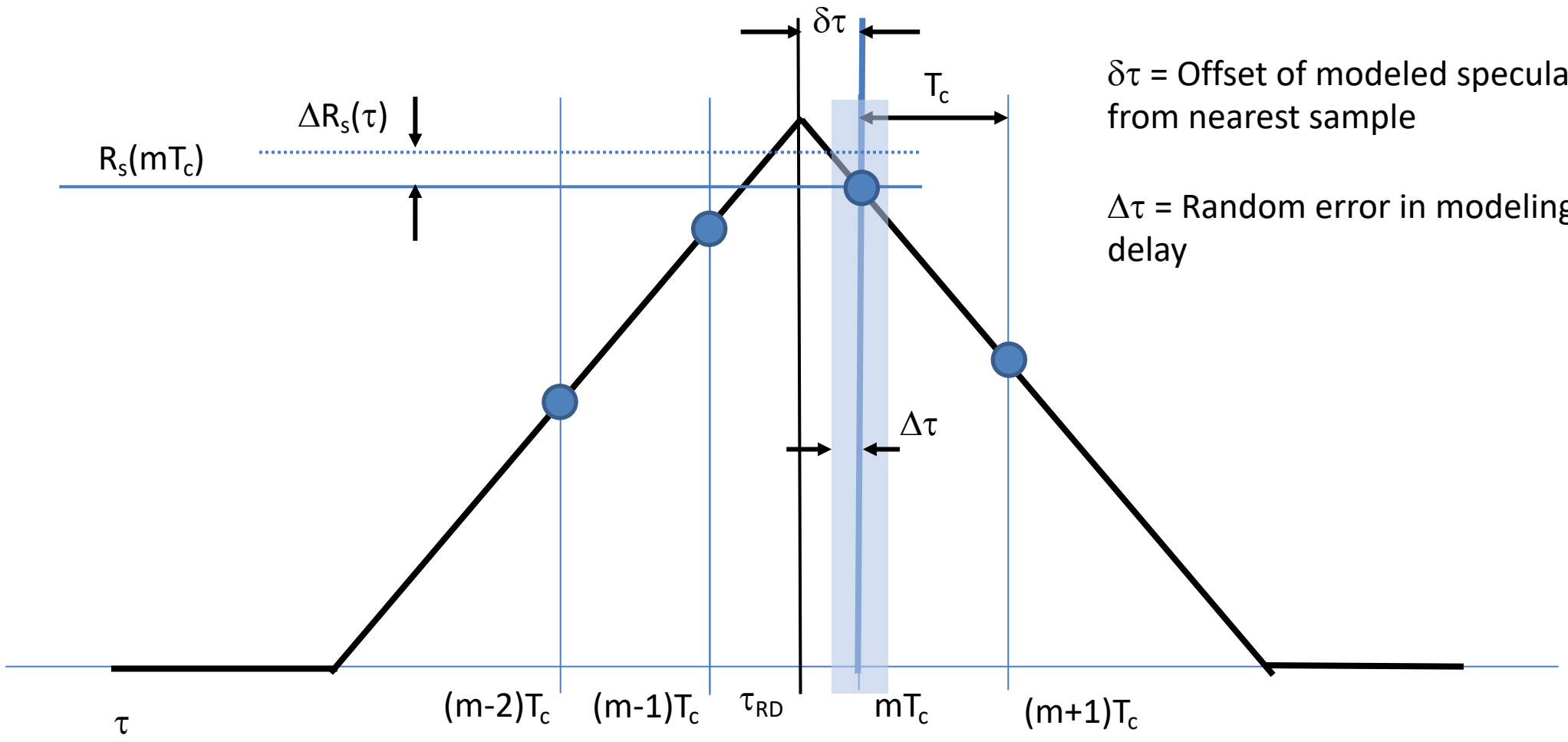
- Test orbit prediction using CYGNSS GPS
  - Orbit error mapped to specular point position error & delay/Doppler uncertainty
  - Includes terrain model
  - SoOp Source position based on publicly available TLEs
- 7-day propagation error:
  - < 9 km specular point position
  - 20 µs delay
  - < 100 Hz Doppler
- Source (MUOS) position error being studied



Instrument Science: Delay-Doppler Map

	255 MHz	370 MHZ
Channel Bandwidth	25 KHz	5 MHZ
Coherent Integration Time (minimum)	1 ms	1 ms
Equiv. “Chip” length	12 km	60 m
Delay Resolution	0.05 chip	0.25 chip
Doppler Resolution	500 Hz	500 Hz
Delay Bins	5	200
Doppler Bins	3	3
Channels	5	1
Bits/DDM	2400	19,200

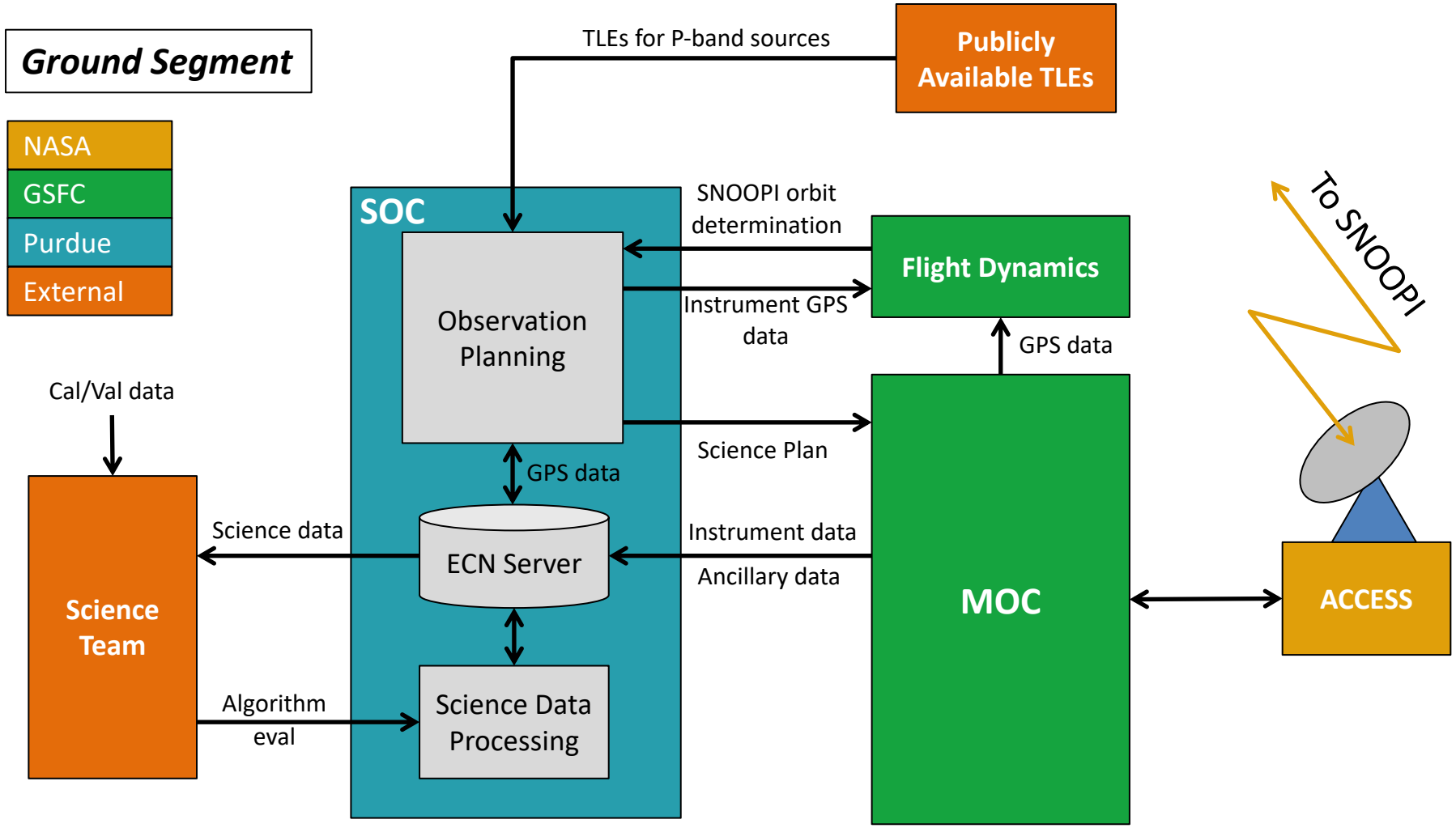
Delay-Doppler Impact on Error Budget



$\delta\tau$ = Offset of modeled specular point delay from nearest sample

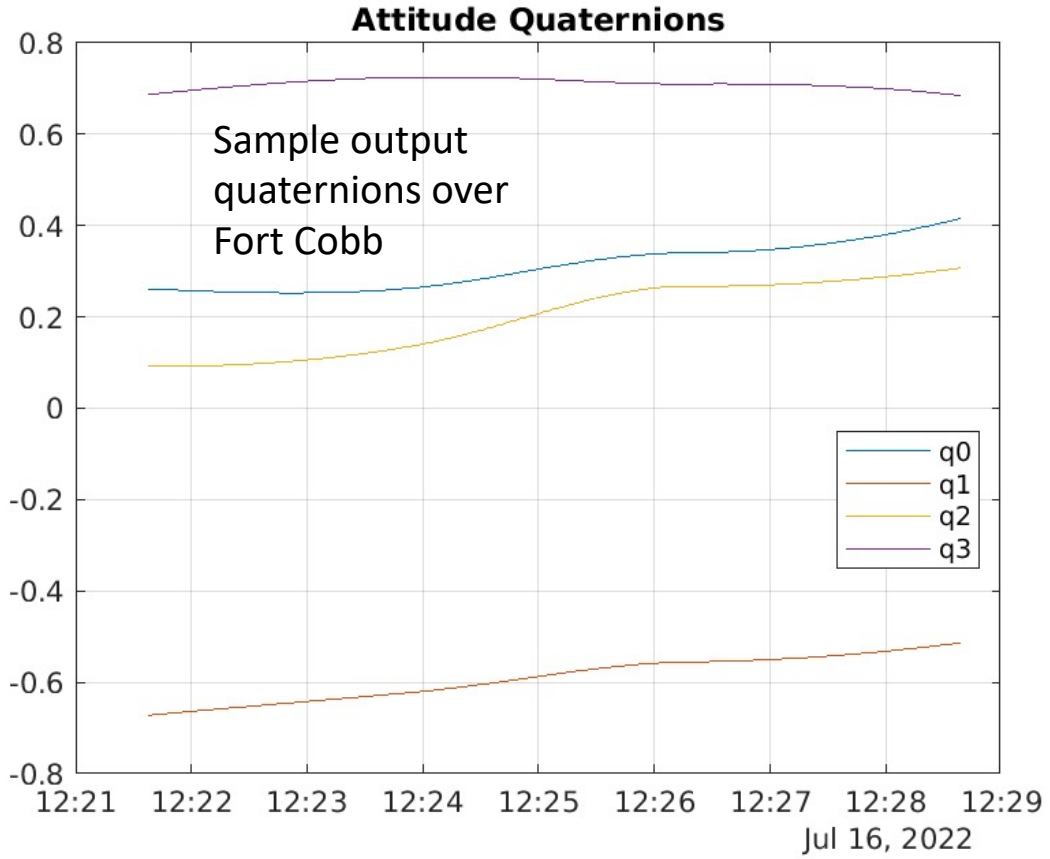
$\Delta\tau$ = Random error in modeling/predicting delay

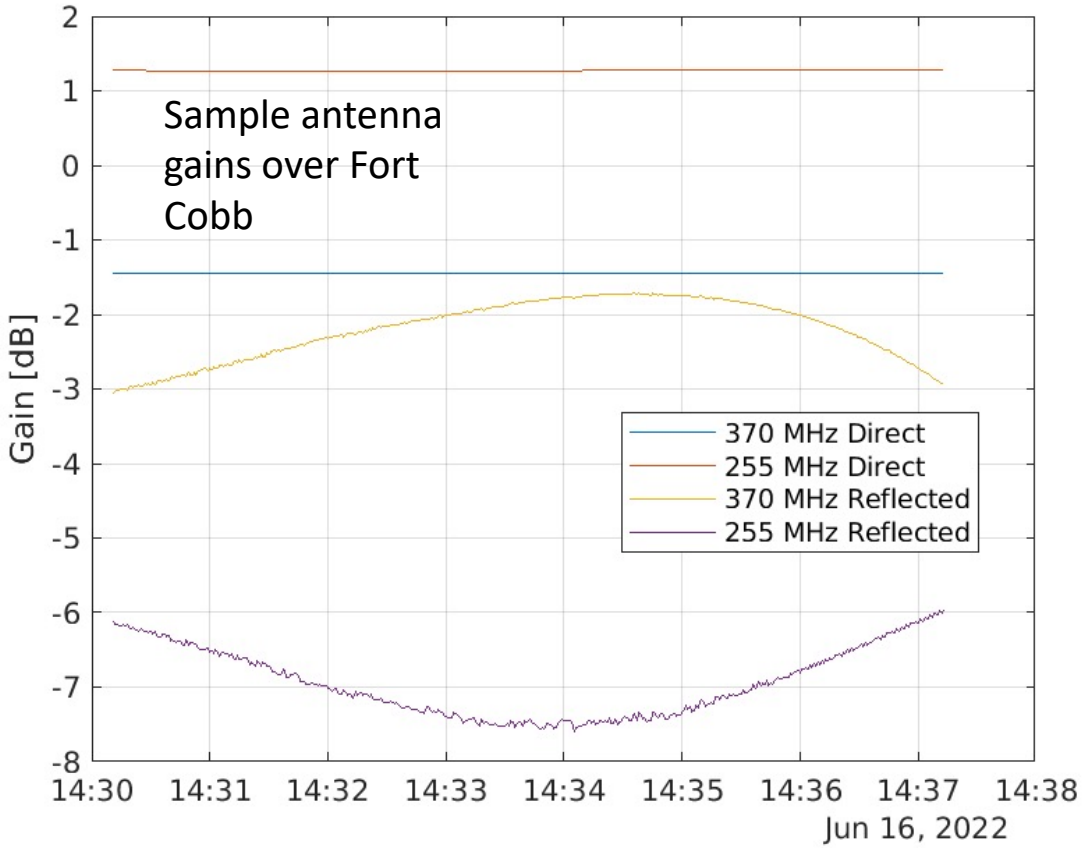
Science Operation Center (SOC)



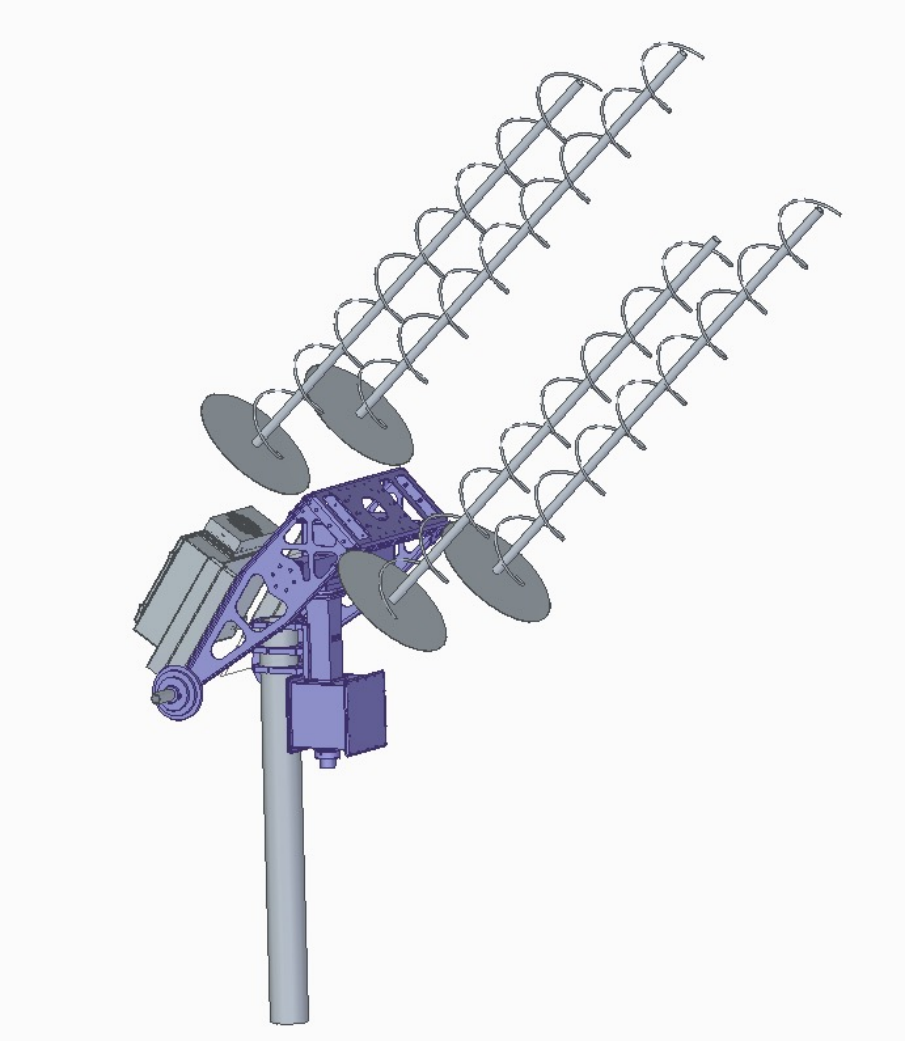
Science Operations Center (SOC)

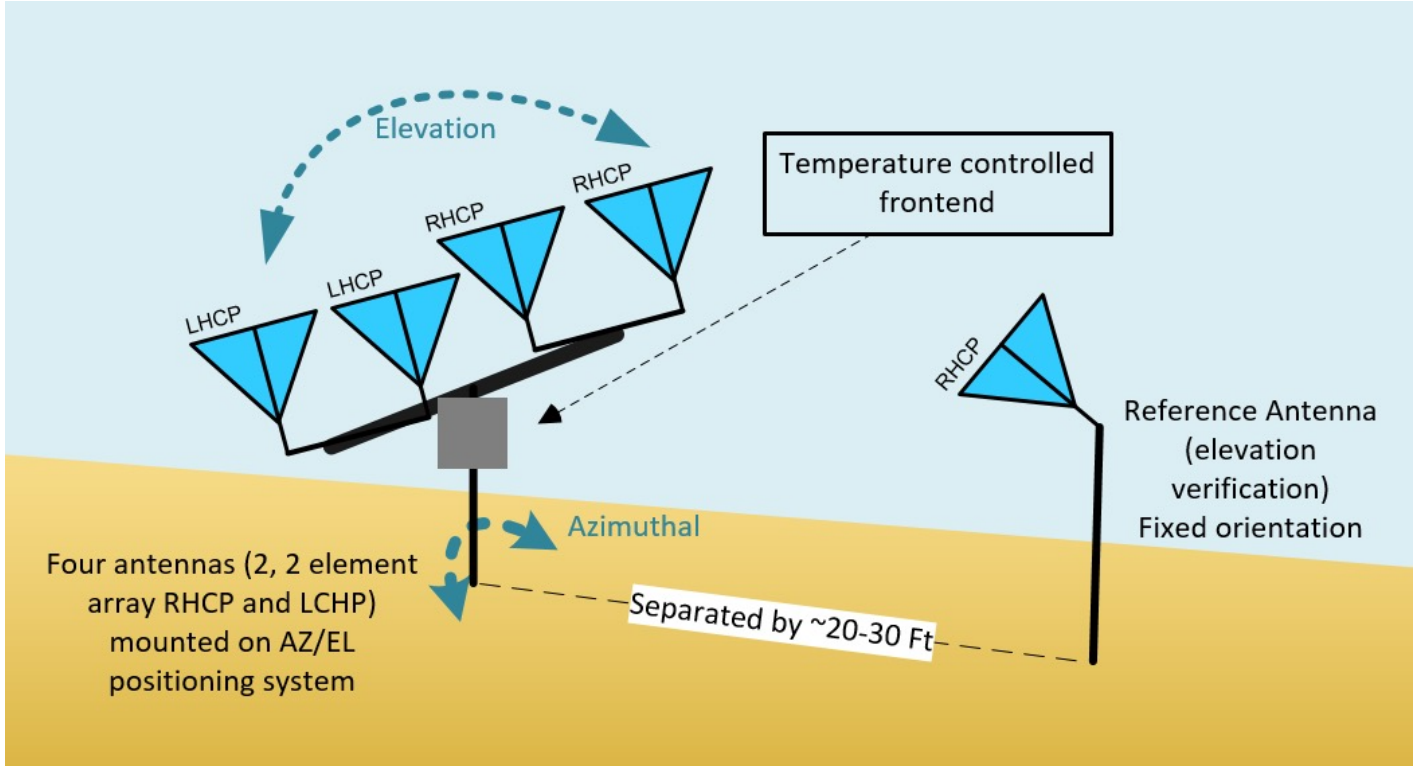
- SOC function: Generate attitude control commands for optimal antenna pointing





EIRP/Ambiguity Function Monitor





- 50 MHz recording bandwidth
- COTS sky scanning antenna positioner system
- Temperature controlled enclosure

Schedule and Milestones

Bus Integration	Aug 2021
Instrument I&T	Sep 2021
Environmental Test	Jan 2022
Ship to Nanoracks	Feb 2022
Launch	Apr 2022 (TBD)
ISS Deployment	Jun 2022 (TBD)
Commissioning	Jul 2022
Science Mission	Jul 2022-Apr 2023
Final Report/Closeout	May 2023

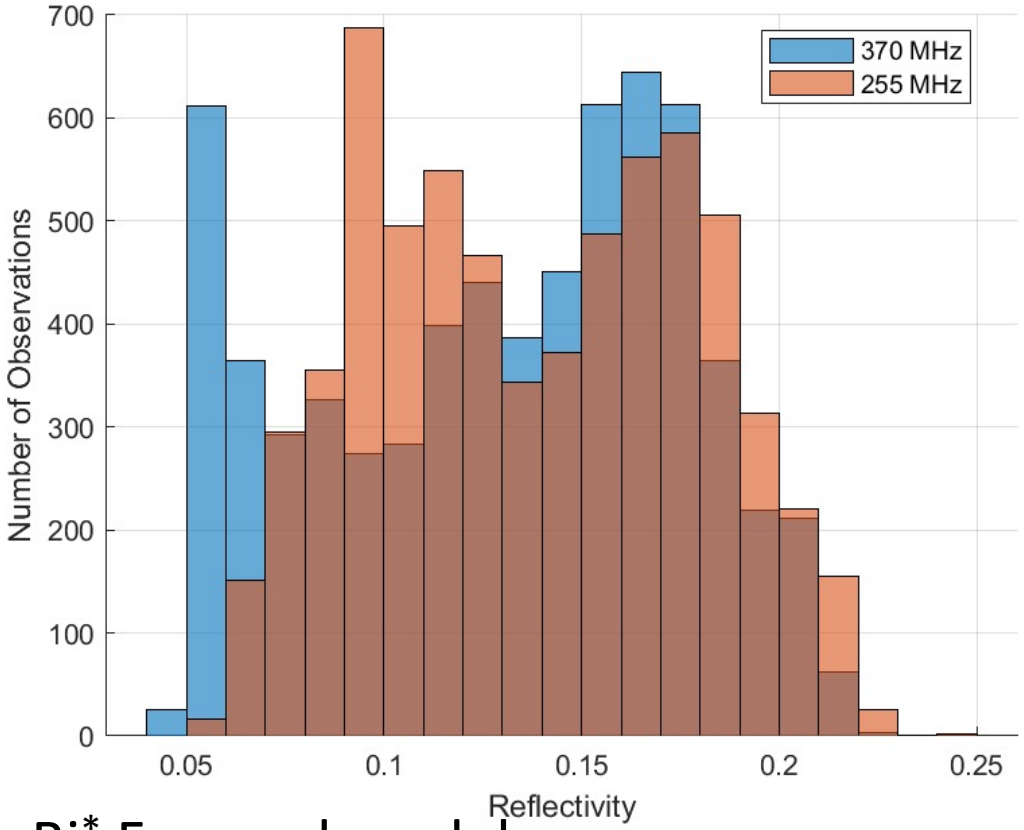
Acknowledgement

This work was supported by NASA Grant 80NSSC18K1524,
"Signals of Opportunity P-band Investigation (SNOOPI)"

BACKUP

Mission Design

- Expected reflectivity observations

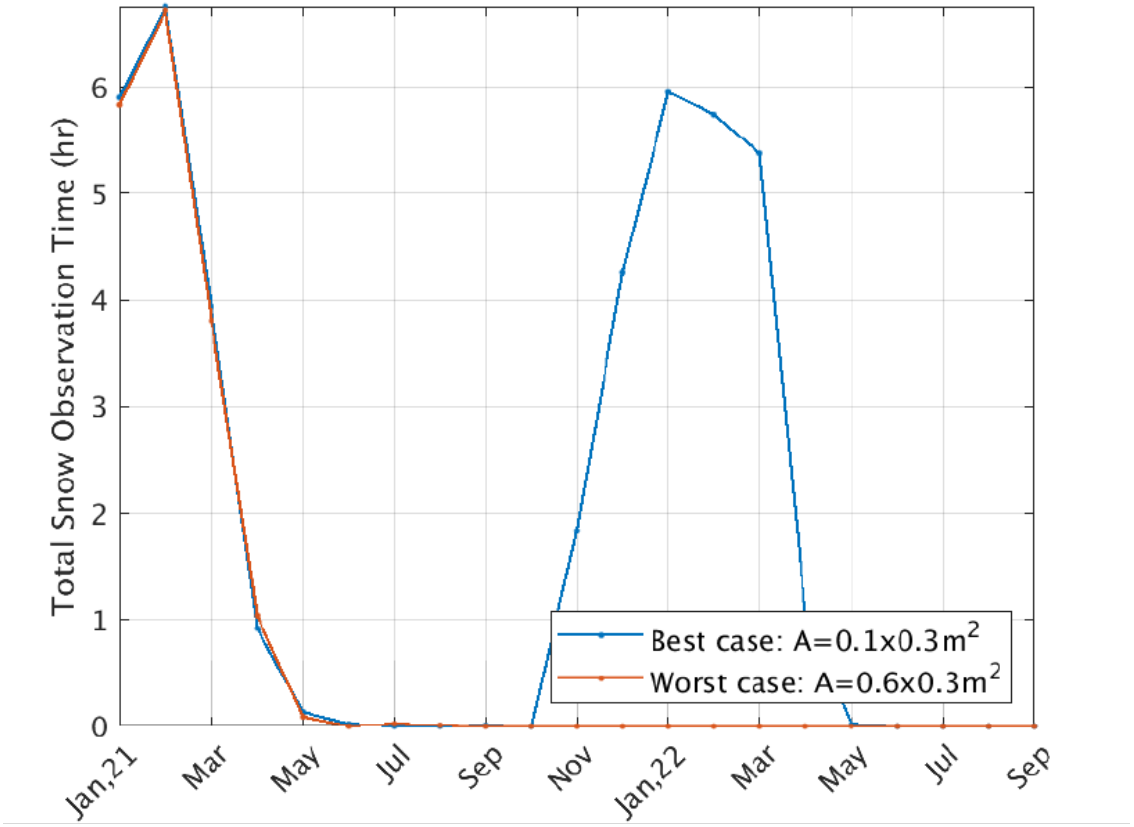


9 SMAP Cal/Val sites, SCoBi* Forward model

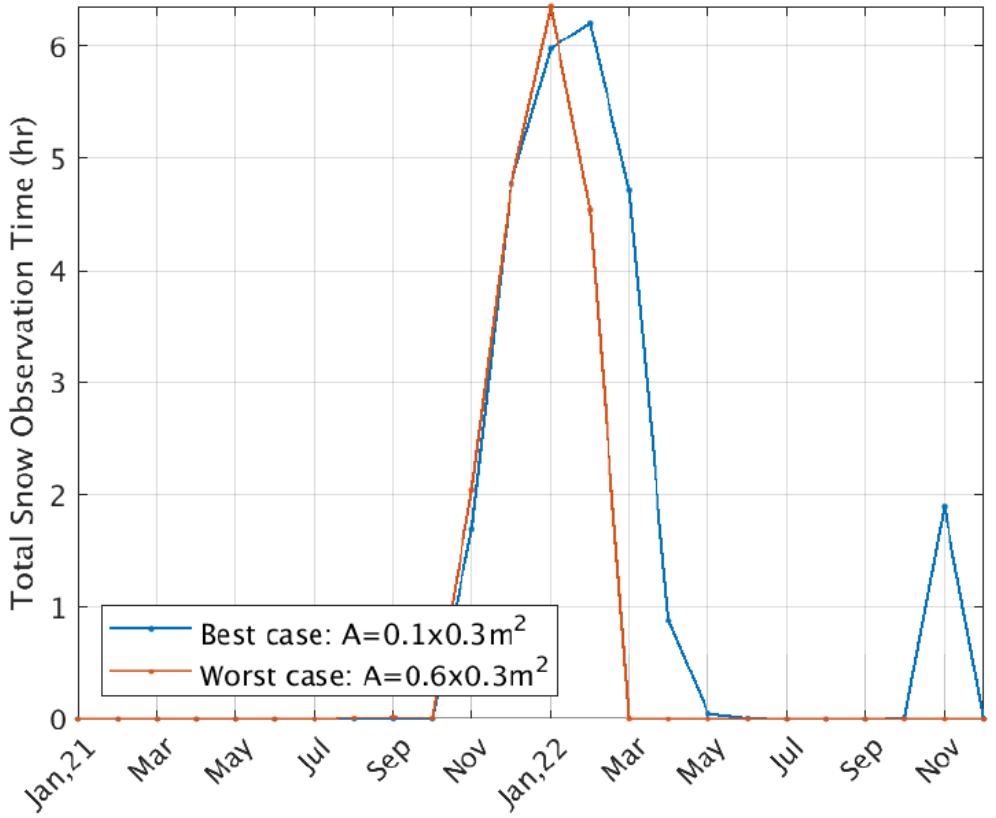
*http://impress.ece.msstate.edu/impress-lab/software/scobi/

Coverage-SNOW

Snow Coverage: Modeling Orbital Decay



(a) Launch in January



(c) Launch in August